the cloud which the balloon entered was the same as that observed in the nephoscope, and while it is not certain that the cloud entered was part of the lowest layer of strato-cumulus, the circumstances seem to justify the assumption that the nephoscope observation is applicable to the place where the balloon disappeared. In the first place the direction of motion of the cloud as observed was from 122° and that of the balloon during the last minute of flight was from 120°. Above this lowest (?) series of strato-cumulus bands were two others; the next higher (?) one was from 130 to 135° at a speed of 5.9 to 6.4 m/s for each kilometer of elevation, and the highest (?) was from 130° at a speed of 3.7 m/s for each kilometer of elevation. It was estimated at the time that the highest layer was at about 3 kilometers.

Assuming that the balloon entered the lowest layer of strato-cumulus, which were moving at the rate of 7 m/s for every thousand feet of elevation, it should have been moving at the rate of 12.6 m/s at the 1,800 meter level (the assumed altitude). If it had been moving at that rate, however, during the last minute of flight, it would have been carried out to a point 756 meters beyond where it was at the end of the eighth minute, or to a point 7,416 meters from the station. At that point, with an elevation angle of 14.3° as observed, the height of the balloon would have been 1,890 meters, which in turn would give us a velocity of 13.2 m/s, as the nephoscope readings indicated a velocity of 7 m/s for every kilometer of elevation.

Assuming a velocity of 13.2 m/s we carry the approximation one step farther, and obtain a distance out of 7,452 meters, an altitude of 1,900 meters, and a velocity of 13.3 m/s. Further approximations do not materially alter this result.

Since the balloon was so inflated as to reach 1,800 meters in 9 minutes under ordinary conditions, it appears to have gained 100 meters during the last minute of its flight on account of ascensional air currents.

A CONTRIBUTION TO THE METEOROLOGY OF THE ENGLISH CHANNEL.

By HUGH D. GRANT.

[Noted from *The Aeronautical Journal*, January, 1921, pp. 25-38.]

Owing to the notorious capriciousness of the weather of the English Channel, and to the vast dependence of transchannel navigation, both marine and aerial, upon these vagaries, this study has been made. It is an attempt to analyze the barometric disturbances which give rise to the channel weather, and the relation of the topography to the sudden changes which occur. Winds, in mid-channel and along the coast, were studied; the latter were investigated by means of pilot balloons which were filled so as to be in equilibrium in the surface air, and by this means a very good idea of the turbulence and gusts along the steep cliffs between Dover and Folkestone was obtained. Fogs, thunderstorms, gales, and squalls are also considered. It is pointed out that the number of well-equipped observatories and dense population on both sides of the channel afford unusual advantages to the investigator, owing to the large number of voluntary observers.—*C. L. M.*

PILOT-BALLOON WORK IN CANADA.

By J. PATTERSON.

[Presented before the American Meteorological Society, Chicago, Dec. 28, 1920.]

(Author's Abstract.)

The Meteorological Service of Canada in conjunction with the Air Board of Canada has established a series of pilot-balloon stations across the country. Last year stations were opened at Vancouver, British Columbia, Morley Alta (near Calgary), Camp Borton, Toronto, and Ottawa, Ontario, and Roberval (Lake St. John), Quebec. It is the intention to open stations this spring at Peace River Crossing and Fort Good Hope on the MacKenzie River. The one theodolite method was used and results plotted in the usual way.

THE MAKING OF UPPER-AIR PRESSURE MAPS FROM OBSERVED WIND VELOCITIES.[1]

By C. LEROY MEISINGER.

[Weather Bureau, Washington, D. C., Nov. 27, 1920.]

SYNOPSIS.

If the equation which expresses the relation between the speed of the wind and the distribution of barometric pressure be solved for the gradient in terms of the observed speed, density of the air, radius of curvature of the wind path, and latitude, it is possible to work out a fairly accurate map of the distribution of barometric pressure at upper levels. This has been done for the observations made about 8 a. m., March 27, 1920, at most of the aerological stations of the Weather Bureau and the Signal Corps. The pressures observed by kites, when used in connection with the computed gradients, give the clue to the values of the absolute pressures at the level in question. Maps of the 1, 2, and 3 kilometer levels were thus constructed.

The gradient wind.—If it is assumed, as is usually justifiable, that the effect of the friction of the earth's surface is negligible at about 500 meters above the surface, it should be possible to use observed wind velocities as a basis for determining the distribution of pressure aloft. The gradient wind equation is frequently used to determine the speed of the wind, using as a basis the sea-level distribution of pressure, but it is obvious that, by solving the equation for the gradient in terms of the speed, the density of the air, the radius of curvature of the wind path, and the latitude, an accurate upper-air map ought to result if based upon sufficient observations. Pilot-balloon observations give only wind speed and direction at various heights; and with these data alone it is possible to determine the gradient but not the absolute pressure. This deficiency may be supplied by kite observations which, when reduced, give the absolute value of the pressure at various levels. Since wind direction is an index to the direction of the isobar and, therefore, the gradient, (the latter being normal to the former) we are enabled to determine quite accurately the radius of curvature of the path. The density may be determined from kite data also. Thus we have all the necessary values to substitute in the equation.

If we take the three equations for the velocity of the gradient wind, as given by Dr. W. J. Humphreys,[2] namely:

$$(1)\ \ldots\ v=\sqrt{\frac{r}{\rho}\frac{dp}{dn}+(r\omega\sin\phi)^2}-r\omega\sin\phi \text{ for cyclones;}$$

$$(2)\ \ldots\ v=\frac{\frac{dp}{dn}}{2\omega\rho\sin\phi} \text{ for straight isobars;}$$

$$(3)\ \ldots\ v=r\omega\sin\phi-\sqrt{(r\omega\sin\phi)^2-\frac{r}{\rho}\frac{dp}{dn}} \text{ for anticyclones,}$$

and solve them for $\frac{dp}{dn}$, we obtain, respectively,

[1] Presented before the American Meteorological Society at Chicago, Dec. 28, 1920.

[2] *The Physics of the Air*, Franklin Institute, 1920, pp. 139-140.

(4) . . . $\frac{dp}{dn}=\frac{\rho}{r}(v^2+2vr\omega \sin \phi)$ for cyclones,

(5) . . . $\frac{dp}{dn}=2v\omega\rho \sin \phi$ for straight isobars;

(6) . . . $\frac{dp}{dn}=\frac{\rho}{r}(2vr\omega \sin \phi-v^2)$ for anticyclones;

in which v is the velocity, $\frac{dp}{dn}$ is the difference in pressure per unit horizontal distance normal to the isobars $r=r_1 \sec \alpha$, where r_1 is the radius of curvature of the wind path, and α is the angular radius of the circle upon which the air is moving measured from the center of the earth; ρ is the density of the air; ω the angle through which the earth turns in a second; and ϕ is the latitude of the place.

Since the difference between r and r_1 is usually small, and, in this case, the value is only an approximation, it is possible to regard them as equal. It is noticed further that the three equations which have been solved for $\frac{dp}{dn}$ contain the term $2\omega\rho$. For a given level, this may be considered as a constant, since we may assume the value of the density constant for a given level. The value of the density used was that given by Dr. H. H. Kimball as standard.[3] The angular velocity of the earth's rotation is, of course, $\frac{2\pi}{86,164}$. These factors when multiplied together give a constant for the level in question. For it the following values of this constant have been computed:

Altitude (km.).	ρ (kg/m³).	Constant $\left(\frac{4\pi\rho}{86,164}\right)$
1	1.104	161×10^{-6}
2	0.996	145×10^{-6}
3	0.896	131×10^{-6}

The computations.—Owing to the difficulty in obtaining an accurate estimate of the radius of curvature of the wind path, and the fact that, in general, such radii are very large, it has been suggested that only the straight-isobar equation be employed in this connection. This would have the advantage of making the computation somewhat simpler. It is doubtful, however, whether this equation should be used universally in determining the pressure gradient. Reference to figure 40, page 143, in the "Physics of the Air" shows what the error would amount to in meters per second when the velocity is determined by equations (1), (2), or (3). The diagram is computed for latitude 40° and a pressure gradient of 1 millimeter of mercury per 100 kilometers. It is seen that when the radius of curvature is very large, greater than 1,200 kilometers, the agreement between equations (1) and (2) and between (3) and (2) is within 2 meters per second. With radii less than 1,200 meters, however, the discrepancy becomes rapidly larger, especially in the case of the anticyclone where, under these conditions, the radius of the critical isobar is about 600 kilometers; at this radius the difference between equations (3) and (2) amounts to slightly over 7 meters per second. Between equations (1) and (2) the difference at 600-kilometer radius is about 2 meters per second, and at 100-kilometer radius the difference amounts to about 6 meters per second. These discrepancies seem to be sufficiently large to demand the use of the cyclone and anticyclone equations where the radii are short.

[3] Kimball, Herbert H.: On relations of atmospheric pressure, temperature, and density to altitude. MONTHLY WEATHER REVIEW, March, 1919, 47:156-158.

The question of which equation to use in solving for the gradient was answered by inspection of the preliminary charts of wind stream lines which were sketched from the wind directions as observed. It is possible with these data to procede to the solution. The following table gives the observed data as to wind direction and speed at the 1, 2, and 3 kilometer levels from pilot balloons and kites:

TABLE 1.—*Observed wind directions, and speeds.*

Station.	1 kilometer.		2 kilometers.		3 kilometers.	
	Direction.	Speed.	Direction.	Speed.	Direction.	Speed.
		m/s.		*m/s.*		*m/s.*
Denver, Colo.			NW.	4		
Fort Sill, Okla	SSW.	27				
Ellendale	NE.	6	SSE.	5	SW.	11
Drexel	SSW.	19	SSW.	19		
Broken Arrow	SSW.	20				
Kelly Field	SSW.	7	SW.	15	WSW.	19
Madison	S.	8	SW.	12	WSW.	8
Lansing	NNW.	16	NW.	20	NW.	22
Royal Center	WNW.	8	W.	16	WNW.	16
Camp Knox	WSW.	9	W.	12	WNW.	11
Leesburg	NW.	5	NW.	3	WSW.	14
Mitchel Field	W.	14				
Aberdeen	W.	19	WNW.	17		
Washington	WNW.	21				
Camp Vail	W.	18				
Fort Monroe	W.	10	WNW.	17	WNW.	25
Camp Bragg	WNW.	9	W.	11		

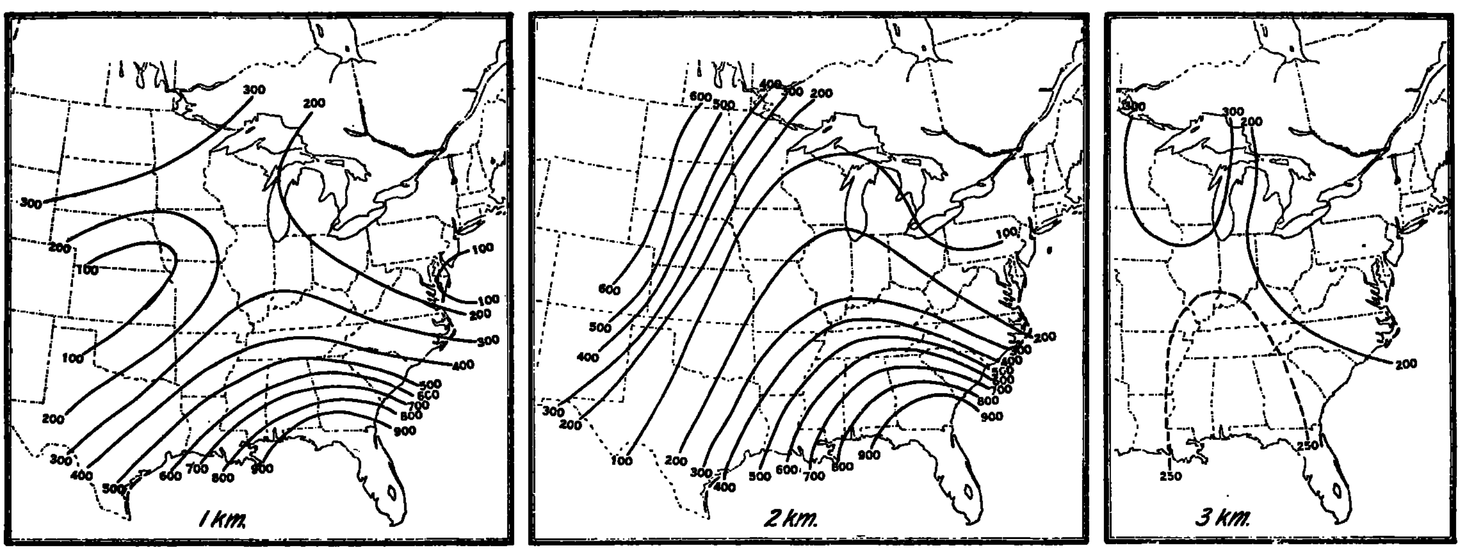
In Table 2 are given the data from which it is possible to draw the isobaric maps of the upper levels. For each level the data include the value of the gradient in millibars per 100 km. horizontal distance, the distance between isobars in kilometers for pressure intervals of 2.5 millibars, the actual pressure observed with kites in millibars, and the estimated pressure at several of the kite stations, where the kites did not quite attain the desired altitude. This extrapolation was effected by use of the hypsometric formula, using the greatest altitude attained by the kite as the lower level and the desired altitude as the upper level, and using as the mean temperature of the air column that value of temperature which would have been attained at the middle of the intervening air column had the vertical gradient continued at the rate observed at the highest point in the flight. This gives a value of the pressure at the upper level which is probably very nearly correct. This operation was performed in the case of Ellendale and Broken Arrow for the 2-kilometer level, and for Ellendale, Drexel, and Broken Arrow for the 3-kilometer level.

TABLE 2.—*Observed pressures and computed gradients.*

Station.	1 kilometer.				2 kilometers.				3 kilometers.			
	$\frac{dp}{dn}$ (mb/100 km.).	Distance between isobars (km.).	Observed pressure (mb.).	Estimated pressure (mb.).	$\frac{dp}{dn}$ (mb/100 km.).	Distance between isobars (km.).	Observed pressure (mb.).	Estimated pressure (mb.).	$\frac{dp}{dn}$ (mb/100 km.).	Distance between isobars (km.).	Observed pressure (mb.).	Estimated pressure (mb.).
Denver					0.4	641						
Fort Sill	2.5	102										
Ellendale	0.8	352	881.6		0.5	481		778.2	1.1	240		685.6
Drexel	2.8	92	883.0		2.5	102	783.8					693.[illegible]
Broken Arrow	2.0	121	893.4					793.6				702.5
Kelly Field	0.5	481			1.2	213			1.2	213		
Madison	0.9	273			1.3	192			0.7	385		
Lansing	1.3	192			2.4	105			1.3	192		
Royal Center	0.9	273	898.8		1.2	213	796.2		1.2	213	703.0	
Camp Knox	0.8	352			0.8	352			0.9	273		
Leesburg	0.3	962			0.3	962			0.9	273		
Mitchel Field	1.6	159										
Aberdeen	2.2	113			1.8	136						
Washington	2.5	102										
Camp Vail	2.1	121										
Fort Monroe	1.1	240			1.6	159			2.0	121		
Camp Bragg	0.8	352			0.8	352						

AUXILIARY CHARTS.

In order to facilitate the drawing of the maps, auxiliary charts (figs. 1, 2, and 3) were drawn. These figures show the distance between isobars in eastern United States where the interval of pressure is 2.5 mb. The lines of equal distance between isobars are drawn for every 100 kilometers from the data contained in Table 2. By means of these figures, one can tell at any point in the region in question what the distance is between the isobars.



FIGS. 1, 2, and 3.—Auxiliary maps showing distance between isobars in eastern United States at the 1, 2, and 3 kilometer levels, Mar. 27, 1920, 8 a. m., 75th meridian time.

UPPER-AIR PRESSURE MAPS.

Figure 4 shows the distribution of pressure and temperature on the morning of March 27, 1920. The isobars are for sea-level in millibars, and the isotherms are for the surface in degrees, centigrade. Figures 5, 6, and 7 show the distribution of pressure at the 1, 2, and 3 kilometer levels, respectively.

The 3-kilometer map shows the tendency for the low center to shift westward, which is what would be expected, since the inflow of cold dense air in the rear of the cyclone would tend to concentrate a great weight of air in the lower layers with a lower pressure at upper levels. The effect of the HIGH in the southeastern part of the United States, while still strong at the 2-kilometer level has disappeared at the 3-kilometer level. This is shown also by the slight winds at Leesburg up to 2 kilometers which change to strong from the WSW. at the 3-kilometer level.

In one or two cases it will be seen that the station arrow does not exactly coincide with the direction of the isobar nearest the place. This may be due to one of two reasons: either the winds were so gentle that the indicated direction was of little significance, or the legitimate smoothing of the isobar necessitated making it pass the station at an angle slightly at variance with the arrow. It should be remembered that the directions are given only in 16 compass points and for this reason such slight discrepancies can not be avoided.

It will be seen that at the 3-kilometer level the gradient as drawn in figure 3 is somewhat less than that shown in figure 7. This is believed to be justified by the fact that the estimated pressure at Ellendale is more reliable than the value of the gradient. There is no wind record at Ellendale for that elevation, hence it is fair to suppose that figure 3 is less trustworthy than the extrapolated

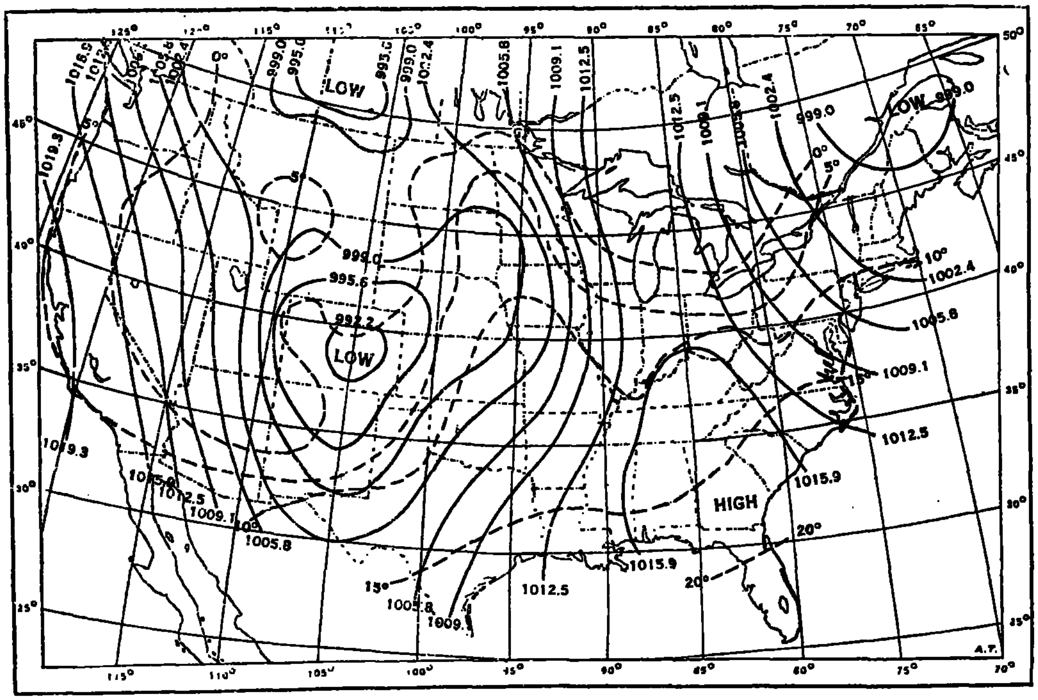


FIG. 4.—Weather map for Mar. 27, 1920, 8 a. m., 75th meridian time. (Pressures in millibars and temperature in degrees centigrade.)

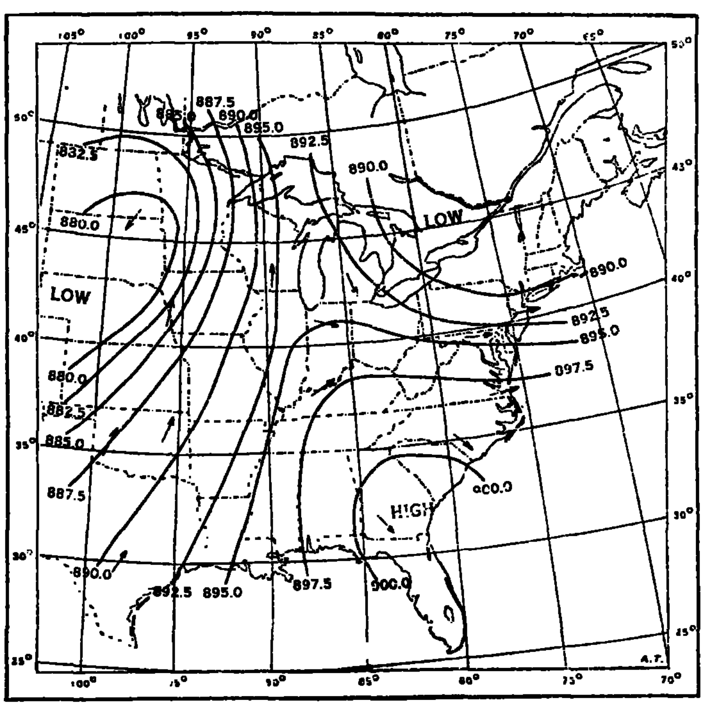


FIG. 5.—Pressure at the 1-kilometer level, in millibars, Mar. 27, 1920, 8 a. m., 75th meridian time.

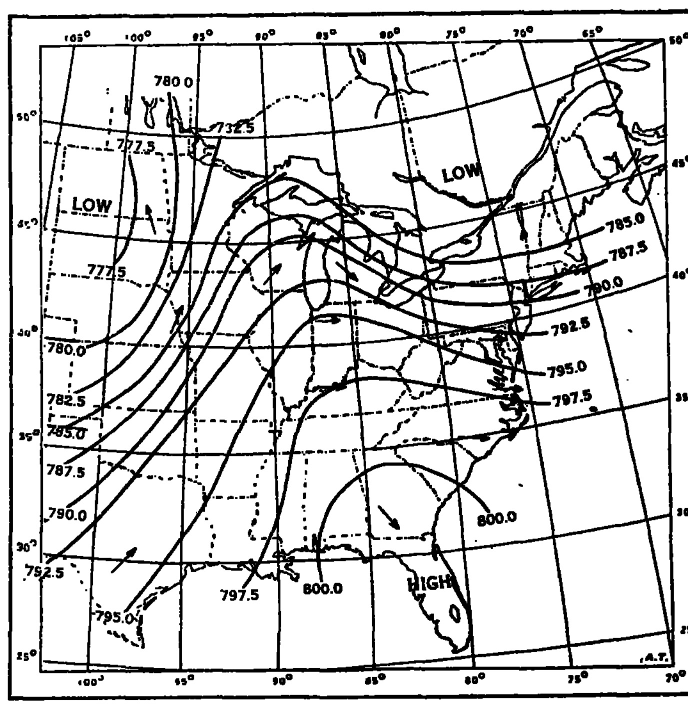


FIG. 6.—Pressure at the 2-kilometer level, in millibars, Mar. 27, 1920, 8 a. m., 75th meridian time.

pressure, and for that reason, the pressure slope has been represented somewhat steeper than the gradient uld indicate.

CONCLUSION.

This short study is an example of the application of the theory of the gradient wind. In spite of the many observational errors that may creep into pilot-balloon data, especially when obtained by the single theodolite method, there is a striking congruity in the figures obtained. It is true that at present the making of such maps by this method is impracticable, not only because of the considerable computation involved, but also because of the number of aerological stations is too small to furnish as much data as would be required. Nevertheless, the difficulties of the proposition lie more largely with external circumstances than with the scientific reasoning. We must improve our methods of forecasting for aviation, and to do it we must have first-hand knowledge of what is going on aloft—not in a desultory and fitful manner, but in a solid, consistent network of aerological stations. Those the Weather Bureau is operating at present are doing excellent work, and the assistance of the Signal Corps is extremely useful, but still this is only a beginning and expansion in the aerological work is one of the greatest needs of the Weather Bureau. Such a method of drawing charts of the upper air may prove to be useful in preparing wind charts for aviators.

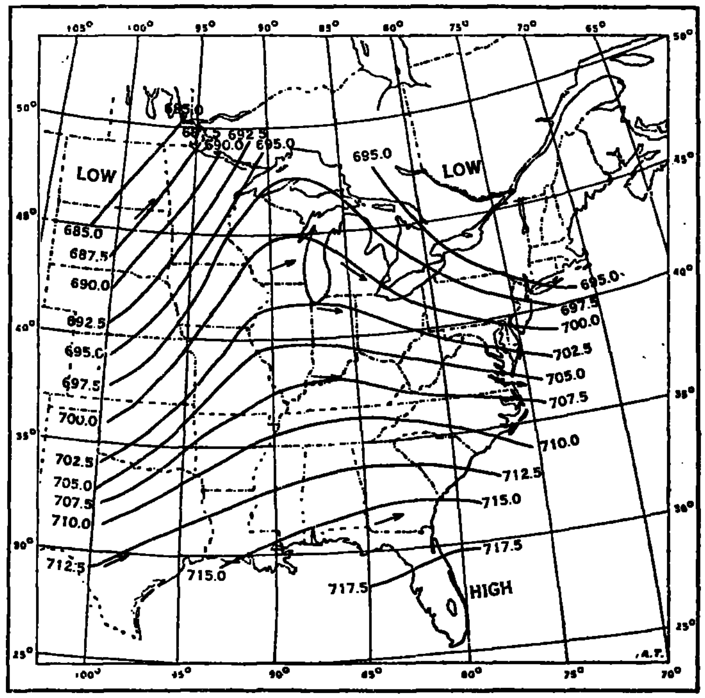


FIG. 7.—Pressure at the 3-kilometer level, in millibars, Mar. 27, 1920, 8 a. m., 75th meridian time.

THE WEATHER FACTOR IN AERONAUTICS.[1]

By C. LEROY MEISINGER.

[Weather Bureau, Washington, D. C., Jan. 20, 1921.]

"Scott and Cooke spend much time at the chart table, measuring angles of drift and calculating the course. Aerial navigation is more complicated than navigation on the surface of the sea, but there is no reason why, when we know more about the air and its peculiarities, it should not be made just as accurate."—Brig. Gen. Maitland, in the log of the R. 34.

SYNOPSIS.

Despite the significant advances of commercial aeronautics since the war, there remains a singular indifference of the public to the enterprise. It is believed that a recognition of the importance of the weather factor will assist in overcoming this indifference through the increase of safety and efficiency. Since lighter-than-air and heavier-than-air craft each have an important place in the scheme of aerial transport, their respective functions must be understood; the former is the probable carrier for long, non-stop flights, and the latter for the short fast flights.

The effect of winds on aircraft may be summed up in an equation, which expresses the speed along the course:

$$V = V_a \cos\theta_1 - V_w \cos\theta$$

wherein V_a is the still-air speed of the craft, V_w the wind speed, θ_1 the angle the craft must turn relative to its course to overcome the effect of drift and θ the angle between the wind direction and the course.

The experience of great European commercial aerial transport enterprises has indicated that the development of this form of transportation will naturally evolve a field for the aeronautical meteorologist, whose work will consist essentially in reducing for the benefit of his organization the detailed information for the individual pilots, a function too complex for any governmental agency to handle.

A specific example of the effect of winds on flight is given which indicates the lines along which meteorological information may be organized.

In this connection, one research problem of profound importance is that of the reduction of barometric pressure to levels in the free air. The success of this problem is largely dependent upon the amount of upper-air observations collected.

INTRODUCTION.

Civil aviation in the United States.—The trend of opinion among those who are most conversant with the results of the first years' efforts in commercial aeronautics seems to be that, to the present, these efforts must be regarded as demonstrations rather than as successful business enterprises. Some in America, make it appear that we must look to the other side of the Atlantic for our object lessons in commercial aeronautics, thereby neglecting the excellent large-scale activities of our own mail service and numerous successful smaller enterprises. We are likely to forget that the route between Miami and Habana, while perhaps not so difficult to fly, is about the same length as the much heralded London-Paris route; and that every day the mail planes are successfully flying over laps of such lengths that the famed European routes seem to diminish in importance as examples. We find that our activities are looked upon by European nations with a considerable degree of interest and our Aerial Mail regarded by Maj. Gen. Sir F. H. Sykes, comptroller general of civil aviation, as a "particularly interesting experiment."[2] There are those who point out that a lack of adequate laws is holding in leash numerous enterprises which stand ready to put into operation a large program of aerial transportation. The legal problem involved is of considerable magnitude and profound importance.[3]

Yet with all the interest and encouraging prospects of the efforts, there appears to be a singular indifference on the part of the public to commercial aeronautics. And this may be attributed in a large measure to the lack of publicity given the venture.[4] In any event, the fact must be recognized that the confidence of the public, one of the

[1] Presented, in part, before the American Meteorological Society, at Chicago, Ill., Dec. 28, 1920; and the Philosophical Society of Washington, Feb. 12, 1921.

[2] Civil aviation abroad. *U. S. Air Service*, December, 1920, pp. 24-26.

[3] Davis, Maj. W. Jefferson: Laws of the air. *U. S. Air Service*, December, 1920, pp. 17-20.

[4] Aerial mail as a promoter of commercial aeronautics. Editorial note. *Aerial Age Weekly*, Nov. 29, 1920, p. 315.